REPORT NUMBER: RED-05-01

REPORT ON EARLY DISTRESS (RED)

RETROFIT DOWEL BARS on I-39

FINAL REPORT

JANUARY 2002

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipients Catalog No.
RED-05-01		

4. Title and Subtitle	5. Report Date
Report on Early Distress (RED) Retrofit Dowel Bars on I-39	January 2002
	6. Performing Organization Code
7. Author(s) Joe Wilson, WisDOT Technology Advancement Specialist Amanda Toepel, WisDOT Technology Advancement Assistant	**8. Performing Organization Report No.** WisDOT Report # RED-05-01
9. Performing Organization Name and Address Wisconsin Department of Transportation	**10. Work Unit No. (TRAIS)**
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Wisconsin Department of Transportation Division of Transportation Infrastructure Development Bureau of Highway Construction Technology Advancement Unit 3502 Kinsman Blvd., Madison, WI 53704-2507	**13. Type of Report and Period Covered** Final Report; 1999-2001 **14. Sponsoring Agency Code** WisDOT Study # RED 01-02

15. Supplementary Notes

16. Abstract

This report was initiated in February 2001 to investigate early distress for a one hundred mile (lane miles) retrofit dowel bar (RDB) project constructed from 1999-2000 on I-39 in central Wisconsin. Significant portions of the RDB work was experiencing early distress in the form of deterioration of the mortar material in the dowel bar slots. For this project, three slots were cut in each wheel path and 18 in. x 1-¼ in. dowel bars were inserted into the slots and backfilled with a proprietary mortar mix (ThoRoc 10-60C) to improve load transfer on the jointed plain concrete pavement. RDB is a concrete pavement rehabilitation technique used to correct faulting and improve load transfer between adjacent concrete slabs, thereby extending the pavement's service life. As a result of the problems that have arisen with this rehabilitation technique, a statewide moratorium was issued (Spring of 2001) for all RDB projects until more knowledge is gained on its long-term viability. The general course of this investigation involved checking known RDB projects in the state for signs of the distress, pulling concrete core samples for physical testing (air void analysis, freeze/thaw durability), conducting a national RDB correspondence inquiry with other state DOTs, and close inspection during construction of a small RDB test project (let prior to the moratorium). This report describes the findings of the investigation along with recommendations and an implementation plan to address the problems. The primary cause of the distress is poor freeze/thaw durability of the mortar material. It appears that this has in turn caused secondary distress in the form of spalling at the joints of the original concrete. The use of a mobile mixer could be a marginal contributing factor in the distress due to its inability to produce consistent mix results with pre-blended proprietary patch materials. Rehabilitation of the most distressed areas was being carried out at the time of the release of this report (summer of 2001). As stated above, this report contains the findings of the investigation and recommendations to deal with the problem as well as an implementation plan to deal with any future RDB projects should the moratorium be lifted in the future.

17. Key Words	18. Distribution Statement
Retrofit dowel bar, mortar deterioration, freeze/thaw durability, ThoRoc 10-60C, Early Distress, Scaling, mobile mixer, Dowel bar retrofit, RDB, DBR	Distribution unlimited Authorized for Public Release

19. Security Classif. (of this report)	19. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	36	

REPORT ON EARLY DISTRESS (RED)

Retrofit Dowel Bars on I-39

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WisDOT Highway Research Study # RED 01-02

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JANUARY 2002

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INTRODUCTION

A Report of Early Distress (RED) for I-39 from the Marquette / Columbia County line to STH 54, just south of Stevens Point, Wisconsin in District 4, was initiated in February 2001 to investigate early distress for a 100 lane-mile retrofit dowel bar (RDB) project constructed from 1999-2000. Two other smaller RDB projects constructed in the same time span were inspected and also found to be exhibiting early signs of similar deterioration, albeit to a lesser extent.

Retrofit dowel bar is a concrete pavement rehabilitation technique used to correct faulting and improve load transfer between adjacent concrete slabs, thereby extending the pavement's service life (estimated to be up to 15-20 years). By addressing the root problem of the distress (faulted joints due to lack of a load transfer system) and not just the symptoms (poor ride), an additional reason is given why RDB was chosen as the rehabilitation technique.

Significant portions of the RDB work was experiencing early distress in the form of deterioration of the mortar in the dowel bar slots. The distress or deterioration of the mortar starts at the joint and work its way out in a series of concentric arcs growing deeper and widening out from the joint as the deterioration advances. Scaling of the mortar surface is also evident in isolated areas. The surface loss due to scaling is approximately 1/16 in. – 1/8 in. (as of June, 2001). See photographs in Appendix A on page 22.

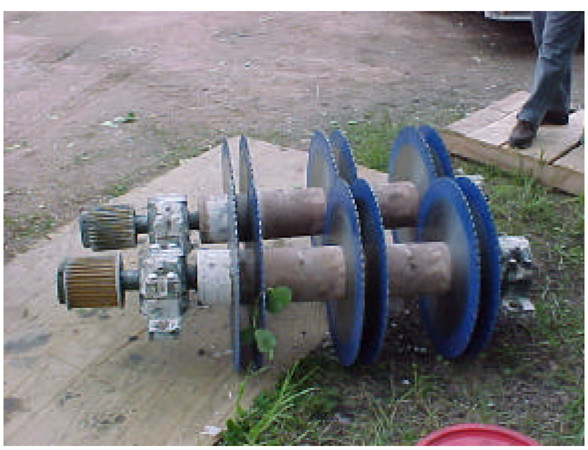
As a result of the problems that have arisen with this rehabilitation technique, a statewide moratorium was issued for all RDB projects until more knowledge is gained on its long-term viability. Thus, an investigation was conducted to determine the probable causes and reasons for the early distress. The general course of this investigation involved checking known RDB projects in the state for similar signs of distress, pulling concrete core samples from the pavements for physical testing (air void analysis and freeze/thaw durability), performing Falling Weight Deflectometer (FWD) testing for load transfer efficiency, conducting a national RDB correspondence inquiry with other state DOT's, and close inspection/observation during construction of a small RDB test project (let prior to the moratorium) on STH 13 in Marshfield, WI. This report describes the findings of the investigation along with recommendations and an implementation plan to address the problems.

CONSTRUCTION PROCESS

For this project (I-39), three slots were cut in each wheel path and 18 in. x 1-¼ in. dowel bars were inserted into the slots. The slots were then backfilled with a proprietary mortar mix (ThoRoc 10-60C). The pavement was then diamond-ground to correct significant load-induced faulting that had occurred on the undoweled, jointed, plain, concrete pavement (JPCP). That is the *general* RDB process; however, the following explains the process in more detail as was observed on the *STH 13* project and reported by Amanda Toepel, WisDOT Technology Advancement Assistant (WisDOT Construction Report "Retrofit Dowel Bars on STH 13", WisDOT Report # WI-10-01). By including the following discussion, it is the intent of the author to give the reader a better understanding of all the steps and nuances associated with a RDB construction project.

Preparing the Slots

A gang saw with 21 in. diameter, diamond-tipped blades was used to make twelve saw cuts across the joint (or transverse crack) parallel to the centerline. The twelve saw cuts resulted in six dowel bar slots per lane (three per wheel path). The slots were 2-½ inches wide and spaced 12 inches apart on center. The photos below show the saw blades and the resultant cuts in the pavement.

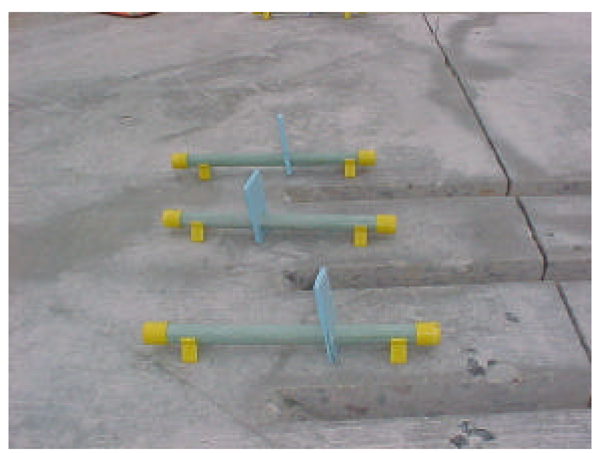


The saw cuts were approximately 37 inches long and 5-½ inches deep to allow the dowel bar to be placed at mid-pavement depth. Thirty-pound jackhammers were used to chip out the concrete between the saw cuts. The slots were then inspected to make sure the "jackhammering" created a level surface at the bottom of the slot where the dowel bar assembly would rest.

Pick axes were used to scrape the concrete debris from the slots after the jackhammer operation. The slots were then sandblasted with abrasive sand. After sandblasting, the sand and other debris were blown out of the slots with compressed air. The slots and sidewalls were then checked to ensure all remaining dust was removed. At that point, any visible micro-cracks were sealed with a siliconized acrylic sealant to prevent mortar from penetrating them (not required as per WisDOT specifications.).

Preparing the Dowel Bars

Two types of dowel bars were used on this project (STH 13). The Nuovinox stainless steel-clad dowel bars were 15 inches long with a 1-¼ in. diameter. These bars were coated with oil that acts as a bond breaker. The photo below on the left shows oil being sprayed on the stainless steel-clad bars. Standard 18 in. x 1-¼ in. epoxy-coated dowel bars (shown on the right) were used on the remainder of the project.



Each dowel bar was fitted with two plastic chairs, two plastic end caps and a foam board as shown above on the right. The chairs allowed the dowel bars to be elevated above the bottom of the slot, providing space underneath them so mortar could fully encase the bar when the slots were backfilled. The end caps had a slight lip around the interior circumference to keep ¼-inch of space between the end of the dowel bar and the end of the cap. The extra space allows for contraction and expansion of the concrete slabs during temperature swings. The piece of foam board was slipped onto the dowel bar and centered to maintain joint integrity.

Placing the Dowel Bars

Prior to placing the dowel bars, a bead of caulk (in the case of STH 13, "siliconized" acrylic sealant) was placed in the bottom of the slot across the joint and on the slot sidewalls to secure and seal the piece of foam board in place. This is done to maintain the joint integrity and also to prevent mortar from flowing into the joint. The dowel bar assembly was then set into place and checked to make sure the foam board lined up with the joint or crack and that the bottom of the foam board was resting in the bead of caulk. The dowel bars were then adjusted to center them as much as possible in relation to the foam board piece. The dowel bar assemblies were also inspected to make sure the chairs were resting on a level surface and the dowel bars were centered between the slot sidewalls. The caulking was checked to make sure that it secured the position of the foam board and sealed any openings where the mortar might seep into the joint or crack.

Calibrating the Mobile Mixer

James Cape and Sons Co., the contractor on this project (STH 13), used a mobile mixer for the majority of the mortar mixes (several different types were used on this project). A mobile mixer is a truck-mounted unit that measures and mixes materials volumetrically. It has separate compartments for aggregate, sand, cement (mortar material) and water. The volume of dry material discharged is regulated and is then dropped onto a conveyor belt and delivered to the mixing screw auger. The dry materials are then mixed with water in the screw auger and discharged.

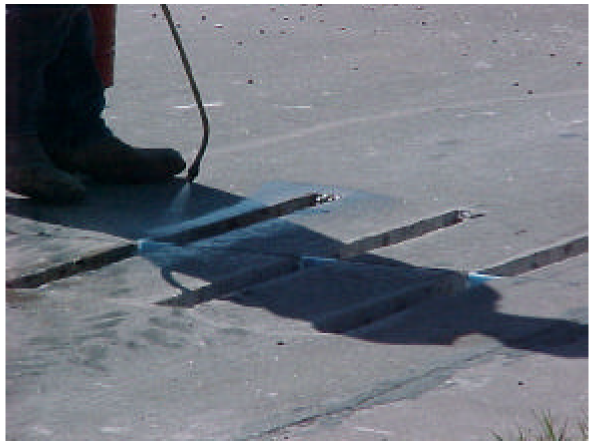
The mobile mixer was calibrated for cement, sand and aggregate before every pour. To calibrate the mobile mixer for cement, the cement was loaded into the cement hopper of the mixer, agitated and dispensed by a metering auger. The mixer was run for a short period of time to push any debris out of the chute until a constant volume of cement was dispensed. Then, the mixer was turned on for ten seconds to dispense the cement out of the chute into a bucket by the mixing auger (see photo on left below). The bucket was then weighed on a digital scale, accurate to ± ½ pound. Ten trials were documented and the average weight of the cement that the mixer dispensed in ten seconds was used to calculate how much sand and aggregate were needed based on the extension ratios recommended by the mortar manufacturers.

Once the cement calibration was complete, the sand was loaded into the sand hopper of the mixer. The mixer was run until any remaining cement had been pushed out of the chute. Then the calibration trials of the sand began, each lasting for ten seconds. The flow control gate to the hopper was adjusted after each set of trials until the mixer consistently dispensed the required amount of sand. The inspector made sure that each time after the gate to the hopper was adjusted, the mixer ran the sand out of the chute as waste until a constant volume was achieved.

The mixer was calibrated for the aggregate the same way it was calibrated for the sand. Once the aggregate calibration was complete, the gates were no longer allowed to be adjusted and the mixer was “ready” to pour.

Pouring the Mortar

Before the pour began, the slots were blown clean one last time with a leaf blower and then wet down with water using a manual pressure sprayer as shown below.



Next, the mobile mixer blended the mortar mix until it reached the proper consistency and then dispensed it into the bucket of a skid-steer.

The workers began the pour by backfilling the mix into the slots with shovels making sure not to damage or disturb the foam board.

As shown in the bottom right photo on the previous page, a spud vibrator with a 1-¼ inch diameter head was inserted into the slot on either side of the foam board (joint) to consolidate the mix around the dowel bar. The filled slots were then leveled off flush with the concrete pavement. The finishers smoothed the surface of the filled slots with a trowel and made sure the foam board was still aligned with the joint or crack.

Care was taken to make sure the backfilling did not get too far ahead of the finishers to avoid having the mortar harden in the slots by the time the finishers reached it. The clean-up crew followed the finishers to scrape any extra mortar off the pavement before it dried and hardened. Lastly, a white-pigmented, wax-type, water-based concrete curing compound was sprayed over the filled slots with a gas powered pressurized sprayer.

Tom Bonnes of James Cape & Sons, Inc., the contractor who performed the RDB work on I-39 and STH 13, stated that "we seemed to have more consistency problems with the mobile mixer when using the pre-blended proprietary patch materials that had the cement and sand pre-blended vs. the concentrate proprietary patch materials."

Finishing the Joint

Within 24 hours of the pour, saw cuts were made to restore the transverse joints or cracks. The saw cuts were made the entire length of the joint and deep enough to remove all patching material from the joint. At the end of the project, the entire concrete roadway was diamond-ground (top left photo below) to remove the previously existing faulting and to provide a smoother ride. Joints were not re-sawn after the backfill operation on previous retrofit dowel bar projects because the existing sealant was left in place except for the slots where it was cut out.

To reiterate, the above section explaining the RDB construction process, as was observed on the STH 13 project in Marshfield, was included to give the reader a better understanding of the nature of RDB work. The process is representative of a typical RDB project.

RDB PROJECT OVERVIEWS (I-39, US 18/151, US 61)

I-39 Project Overview

Highway	: IH-39 North & South, Marquette, Waushara & Portage Counties
Project ID	: 1160-00-60, 1160-01-61 & 1160-01-62
Project Location	: Columbia / Marquette County Line – STH 54 (Approx. 50 miles)
Construction Date	: 1999-2000

The original pavement, an un-doweled, jointed, plain, concrete pavement (JPCP), was constructed from 1980-1987, with most of the work done from 1984-1987. Although the slabs had become significantly faulted, the pavement was in very good shape with very little surface distress, sound joints (limited spalling) and solid concrete at the base of the joints. Thus, RDB was chosen as the technique to rehabilitate and extend the pavement's service life. One hundred lane miles of RDB was constructed on this project.

The mortar used for this project was a proprietary mix called ThoRoc 10-60C (formally called Patchroc 10-60C). It was used at 100% extension, which means that for every "x" amount (by weight) of the proprietary cementitious mix used, the same "x" amount (by weight) of 3/8" minus aggregate was added. It is noted that the contractor used this mix design (100% extension) on the entire job based on the mortar manufacturer's mix design.

US 18/151 Project Overview

Highway	: US 18/151 East & West, Iowa County
Project ID	: 1204-05-71
Project Location	: CTH YZ - Dane / Iowa County Line
Construction Date	: 1999-2000

This was an 11 mile project (44 lane miles) constructed in 1999 and 2000 with the same configuration of three dowel bars in each wheel path. As of March of 2001 this project appeared to be performing well overall; however, there was an isolated area showing early signs of deterioration of the mortar, similar to that which is occurring on I-39. For this project, three different types of mortar mixes were used: 1) ThoRoc 10-60C @ 80% extension, 2) Five Star Highway Patch, and 3) Dayton/Superior RDB mortar.

US 61 Project Overview

Highway	: US 61 North & South, Grant County
Project ID	: 1202-01-72
Project Location	: Mississippi River Bridge – 2 miles north
Construction Date	: 1999-2000

This was a two mile project (8 lane miles) constructed in 1999 and 2000 with the same configuration of three dowel bars in each wheel path. As of March of 2001, some of this project was showing evidence of the same types of distress as that on I-39, mainly deterioration of the mortar at the joints along with some moderate to severe scaling of the mortar. Not all of this project is performing poorly as there are areas performing well. ThoRoc 10-60C was the mortar material used on this project. The product was placed at an 84% extension rate.

PHYSICAL TESTING / ANALYSIS

Core Analysis Findings/Discussion

A total of nineteen five-inch diameter cores, taken from various locations throughout the I-39 project, were tested for hardened air content and freeze/thaw durability; however, four of the nineteen cores obtained in the field could not be used for testing due to their advanced state of deterioration, while four more of the cores were sent to the Construction Technologies Laboratory (CTL) for independent testing as requested by the contractor (James Cape and Sons, Inc.) and the Wisconsin Concrete Pavement Association (WCPA). Thus, eleven cores pulled from the I-39 pavement were tested at the WisDOT Materials Laboratory. Another nine cores were obtained for the same testing from the US 18/151 RDB project; three cores from each of the 3 types of mortar material used on that project (ThoRoc 10-60C, Five Star Highway Patch and Dayton Superior RDB Mortar).

The construction diary kept by WisDOT District 4 Project Engineer, Kevin Garrigan, was analyzed to determine where best to take cores in an effort to eliminate or isolate diverse variables (for example ambient air temperatures during mortar placement, relative mix consistency, good vs. bad performing areas, different aggregate sources, etc.). The cores were taken full depth and thus included a portion of the dowel bar itself.

The WisDOT Concrete Testing Laboratory is under the direction of Mr. James Parry, P.E. (ph. 608-246-7939) who contributed the following discussion/analysis of the test results.

Air Content Analysis

The Air Content testing was conducted as per ASTM C457. For conventional Portland Concrete (PCC), entrained air content and spacing factor are good indicators of concrete durability. As Paul Okomoto of the CTL stated in a May 1, 2001 meeting held at the WisDOT Materials Lab, the proprietary patch materials used for RDB are high alumina cement-based products which may not conform to normal concrete evaluation parameters. It turns out that he was indeed right. Looking at the attached graph (Figure 1 in Appendix B, page 31), it is readily apparent that there is no correlation between air spacing factor and percent weight loss in the freeze/thaw test. There are samples with 100% weight loss in the freeze/thaw test that span the full range of spacing factors. Similarly, there are samples with near 0% loss in the freeze/thaw test that span the full range of spacing factors. Therefore, air content will not be an appropriate parameter for monitoring quality of proprietary patch materials as placed in the field. Freeze/thaw tests are the only direct reliable measure of durability that we have in this case. See Table 2 in Appendix B on page 29 for the complete air content analysis test results.

Freeze/Thaw Durability Testing

Freeze/thaw durability testing involves slicing the cores to extract the RDB slot mortar material and putting the samples in a freeze/thaw chamber and subjecting them to 300 freeze/thaw cycles, in accordance with Method A of ASTM C666. The relative success or failure of any given sample is measured by the percent weight loss after the test is completed. Five of the eleven cores taken from I-39 experienced 100% weight loss after 300 cycles in the freeze/thaw test. The six remaining samples not entirely destroyed after 300 cycles were kept in the freeze/thaw chamber for further testing in an effort to gather additional understanding of the mortar's long-term durability (See Table 2, page 29).

For a frame of reference or as a side note, central Wisconsin gets about 100 *natural* freeze/thaw cycles per year. However, there is NOT a direct correlation between natural freeze/thaw cycles and WisDOT's accelerated laboratory cycles. The rapid lab cycling is much more severe, thus there is not a direct correlation between field and lab freeze/thaw cycles. ASTM C666 (Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing) states that "Neither procedure (A or B) is intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete."

Based upon the testing of core samples from the subject projects placed in 1999 and 2000, none of the mortar materials used had a completely clean track record. Freeze/thaw loss for core samples of ThoRoc 10-60C (@ 100% extension) from I-39 ranged from 0% to 100%. Five of the eleven cores (45%) completely disintegrated in the test (100% weight loss), while one experienced 87% loss, another 31% loss, two showed 12% loss, one 9% loss and one sample showed 0% weight loss. Some of the samples had completely disintegrated after only 80 cycles in the freeze/thaw chamber. In comparison, standard WisDOT concrete mixes have a typical weight loss of approximately 2% after 300 cycles in the freeze/thaw test.

Freeze/thaw loss for the three core samples of Five Star Highway Patch from USH 18/151 ranged from 2% to 30%. Freeze/thaw loss for the three core samples of Dayton Superior (from USH 18/151) RDB Mortar ranged from 0% to 24%. It is interesting to note that the three core samples of ThoRoc 10-60C from the US 18/151 project showed significantly better results (2% - 9% loss) than the same mortar type used on I-39. As noted earlier, the ThoRoc 10-60C used on the US 18/151 project was placed @ 80% extension vs. 100% extension on the I-39 job. Table 2 in Appendix B (pg. 29) contains the freeze/thaw durability test results.

Falling Weight Deflectometer (FWD) Testing

WisDOT's Pavement Engineering Unit assisted in the investigation by performing Falling Weight Deflectometer (FWD) testing to determine how well the dowel bars were providing load transfer between adjacent concrete slabs. A total of 5 general locations were tested on I-39, while an additional 3 general locations were tested on US 18/151 in Iowa County. For each general location, tests were conducted at two to twelve different transverse joints within the general location and at three locations along the transverse joint: edge of pavement (left or right), center of lane, and wheel path (left or right). So the test results then represent average load transfer efficiency (LTE) for the two to twelve places tested within a general location (average value for edge of pavement for the two to twelve locations within a general location, average value for center of lane for the two to twelve locations within a general location and an average value for the wheel path for the two to twelve locations within a general location).

In addition, the test results for each of these three locations along the transverse joint represent the average of multiple tests with varying loads applied. For I-39, four of the five general locations were tested in the driving lane, while the other test was performed in the passing lane. For US 18/151, two of the tests were conducted in the passing lane, while the other site was tested in the driving lane.

The above describes the FWD testing performed on I-39 and US 18/151 in March of 2001. Follow-up testing was performed on I-39 in July 2001. A total of eight general locations were chosen and tests were performed as described above except that the tests were limited to the right wheelpath and the center of the lane between the wheelpaths (the edge of pavement was not re-tested). Testing of the center of the joint between the wheelpaths (no dowel bars) was done for informational purposes. All tests were done in the driving lane. The eight sites chosen included areas where the mortar was performing well, areas with moderate deterioration and areas performing poorly. In addition, the eighth site was an undoweled section that was included for comparison purposes.

As stated above, initial testing for I-39 was performed on March 1, 2001 with follow-up testing performed July 24-25, 2001. It is believed that during the March testing, the subbase was in a frozen condition resulting in higher load transfer results. Conditions for the first day of follow-up testing were sunny skies and ambient air temperatures of 83° - 97° F. with pavement temperatures in the range of 95° - 111° F. These conditions for the first day of follow-up testing also resulted in higher load transfer values due to expansion of the slabs and increased aggregate interlock. Conditions during the second day of follow-up testing were more conducive to obtaining reliable FWD test results. Skies were cloudy to mostly cloudy, joints were open and ambient air temperatures were in the range of 72° - 88° F. with pavement temperatures in the range of 88° - 101° F. Figure 2 in Appendix C (pg. 35) shows the relationship of load transfer efficiency vs. pavement temperature for the follow-up testing on I-39. As the pavement temperature increased, so did the resulting load transfer efficiency. FWD testing for US 18/151 was performed on March 8, 2001. No follow-up testing was performed on that project.

In short, the results from the March, 2001 testing of I-39 showed that load transfer efficiency was adequate and ranged from 0.81 to 0.88 for the wheel path tests (where the dowel bars are). A load transfer efficiency value of 1.0 would mean that the slabs are providing 100% load transfer. For informational purposes, an LTE of 0.7 is considered adequate; an LTE of 0.6 is questionable while an LTE of 0.8 is good. The results from US 18/151 showed that load transfer efficiency was *marginally* adequate, ranging from 0.63 to 0.76 for the wheel path tests; however, these results are inconclusive and were performed for informational purposes. Table 4 in Appendix C on page 33 contains the initial FWD test results.

The test results for the follow-up testing in July of 2001 on I-39 showed that the average load transfer efficiency ranged from 0.71 to 0.95 for the right wheelpath in the doweled sections. The average values for the right wheelpath in the undoweled section ranged from 0.54 to 0.65. The average load transfer efficiency at the center of the joint between the wheelpaths ranged from 0.57 to 0.98 for the doweled sections and 0.42 to 0.47 for the undoweled section. The follow-up FWD test results can be found in Table 5 in Appendix C on page 34.

NATIONAL RDB CORRESPONDENCE INQUIRY WITH OTHER STATE DOTs

As part of a national network of State DOT information sharing, each state has at least one representative on the AASHTO Research Advisory Committee. One of WisDOT’s representatives is David Larson, Supervisor of WisDOT’s Technology Advancement Unit. A photo and a brief explanation of WisDOT’s problem with RDB work was sent out in an effort to learn of other states’ successes and/or failures as it relates to RDB work. Fifteen of the twenty states that responded have either tried or just recently constructed RDB projects. A few states reported no problems thus far; however, most of those projects were relatively new. Overall, most states that have tried RDB reported some kind of problem or another. The responses varied as to the best performing mortar mixes, and both materials and construction problems were reported. The primary mode of failure was either deterioration or debonding of the mortar material.

In addition to the national inquiry, David Larson visited Minnesota to get first-hand knowledge of their experiences with RDB. As a result of this visit, the RAC inquiry, and WisDOT’s own experience with

RDB, several test sections constructed in May and June of 2001, on STH 13 in Marshfield, were tailored to reflect the information/knowledge gained.

STH 13 RDB TEST PROJECT

In May and June of 2001, WisDOT constructed several test sections on STH 13 in the City of Marshfield in an effort to gain a better understanding on the long-term viability of RDB work in Wisconsin. The project length was 9055 feet and included 5.3 lane miles of RDB work. In all, fifteen different test sections were constructed encompassing four different mortar types, sealed vs. unsealed joints and two different dowel bar types. For this project, mortar testing consisted of 7 and 28-day cylinder breaks for compressive strength, 7 and 28-day permeability tests, air content analysis and freeze/thaw durability testing. Laboratory analysis of the cores has been completed, but field performance will be monitored over the next 1-2 winter seasons. Long-term performance monitoring is expected to continue for the remaining life of the pavement. A five-year report will be written documenting the performance of the test sections, the test results, and recommendations for future RDB projects. The mortar mixes and their associated extension rates are tabulated in Table 1 on the next page. Table 3 in Appendix B on page 30 contains the freeze/thaw durability test results. As can be seen in the table, the best performing mortar mixes were the Tamms Speed Crete 2028 and the MnDOT 3U18 Concrete Mix. The other two mortar mixes (American Highway Technologies and ThoRoc) failed the freeze/thaw durability test. As of January 2002, all mortar materials were performing well in the field.

Table 1 STH 13 RDB Test Sections

	Joints UnSealed (Remove Existing Sealant)	Joints Sealed (Hot Asphalt)
MnDOT Specification 3U18 Concrete Mix	1	1
Amer. Hwy. Tech. Dowel Bar Mortar (@ 60% Extension)	1	1
Amer. Hwy. Tech. Dowel Bar Mortar (@ 100% Extension)	1	2
ThoRoc 10-60C (@ 60% Extension)	3	1
Tamms Speed Crete 2028 (@ 80% Extension)	1	1
Tamms Speed Crete 2028 (@ 80% Extension) (15" Nuovinox Stainless Steel Clad Dowel Bars)	1	X
Tamms Speed Crete 2028 (@ 100% Extension)	X	1

Note: All test sections using Standard 18" x 1 1/4" Epoxy-Coated Steel Dowel Bars unless otherwise noted.

AUXILIARY INFORMATION / DISCUSSION

Secondary Distress

It was observed during a field inspection on the I-39 project on July 7, 2001 that secondary distress (spalling of the original concrete at the joints adjacent to the dowel bar slots) appears to be occurring as a result of the primary distress (deterioration of the mortar at the joints). When the mortar deteriorates in the dowel bar slot at the joint, the adjacent original concrete is left "hanging" and exposed, and when combined with subsequent traffic loadings, appears to be causing the original and newly exposed concrete to spall at the joints. This condition is further compounding rehabilitation efforts for the distressed RDB areas.

Transverse Joint Sealant and the Use of Foam Boards

Some other pertinent notes on the I-39 project are pointed out here for informational purposes. One is that the existing joint sealant was left in place except in the slots (where it was cut on either side of the slot to allow placement of the dowel bars). It appears that this condition may be contributing to the distress by trapping water in the joints at the dowel bar locations, not allowing the water that infiltrates to escape or evaporate, and perhaps contributing to freeze/thaw distresses. In addition, this particular sealant condition may actually be channeling water to the foam board. During inspection of various PCC rehabilitation projects (partial depth repair) around the state, it was observed that the worst performing patches were those with a similar joint sealant condition (partial seal), while the best performing patches were associated with well sealed joints or no joint sealant at all. Field inspections of the foam board pieces indicated that they are acting like sponges. By squeezing the foam board pieces, one can observe water running out of them. It appears they're acting like wicks as well, drawing water down into the joints and holding it there for several days after precipitation events.

Caulking/Void Filling

For the STH 13 project, a significant amount of time was spent caulk filling voids at the base of some of the more deteriorated joints. It is noted in this report that the contractor was looking for some kind of direction from WisDOT staff on what material(s) would be most practical for void filling, thus Jim Parry, WisDOT Concrete Materials Engineer, was contacted and recommended sand to fill the voids. This caused less than favorable results upon final cleaning of the slots with compressed air. Should any future RDB work be done, this issue should be formally addressed at the pre-construction meeting.

RDB vs. Full Depth Repair

It was noted on the STH 13 project that some of the joints were in questionable condition for RDB, i.e. the concrete at the base of the transverse joint was deteriorated on either side resulting in a "triangular" void such that the effectiveness of retrofitting those particular joints was questioned. The contractor was looking for some kind of guidance relating to this; namely, at what level of deterioration does a particular joint call for a full depth repair vs. a retrofit dowel bar?

Slot Sawing

It was observed on the STH 13 project that numerous slots were cut that were not centered on the joint. In some cases the slots were misaligned by a third, i.e. 1/3 of the slot was on one side of the joint while the remaining 2/3's of the slot fell on the other side of the joint. This caused some of the dowel bars to not lie flat on the bottom of the slot due to the upwardly curved nature of the sawn slots on either end. This is noted here for informational purposes, as well as offering a potential contributing cause for any future failure(s).

Mobile Mixers

After following the STH 13 RDB project, and after correspondence with other state DOTs, it has become apparent that WisDOT needs to look at the bigger picture of the use of a mobile mixer with respect to its ability to provide consistent mix results on RDB projects utilizing proprietary mortar mixes. After much down time trouble shooting and calibrating the mobile mixer on the STH 13 project, a paddle mixer was finally utilized in an effort to get more consistency in the mortar mixes. Some states have banned the use of the mobile mixer because of this and WisDOT should consider this too, if RDB is to be continued in the future in Wisconsin. The key is to calibrate the machine daily and a skilled, attentive operator is imperative.

In addition, the auger doesn't touch the bottom of the chute, so it is possible that the finer cementitious materials are resting on the bottom of the chute, thus mixing only some of the cementitious material with the aggregate and water.

Jack Hammer Use to Chip Out the Dowel Bar Slots

This topic is included here mainly for informational purposes. It was learned during the RAC inquiry that the State of Michigan experienced problems when they allowed the contractors to use a heavier backhoe-mounted jack hammer (greater than 60 pounds), for production purposes, than was called for in their specifications (30 pounds). It appears that this resulted in pavement break-up at the base of the concrete, and subsequent distress of the RDB work. They believed that the large jackhammers caused breakouts or micro cracking in the bottom of the pavement, then when trucks started running on the finished slots “punchdowns” occurred. A check of WisDOT special provisions found that the maximum rated jackhammer to be used to chip out the slots is 30 pounds (lighter if the pavement is damaged with the 30 pound hammer), thus this information is included as something for WisDOT project engineers to be cognizant of should any more RDB projects be constructed in Wisconsin. The picture below (Michigan Pavement) contains an example of the “punchdown” as described above. Wisconsin Concrete Pavement Association President, Kevin McMullen, adds that an inquiry to the Michigan DOT about the possible cause for the distress, “…centered on the fact that the pavement had mesh in it and thus hampered the removal of the slots.”

CONCLUSIONS

1. At the current time there is insufficient data to make a decision to resume letting RDB contracts. Laboratory analysis of the cores from the RDB research project on STH 13 in Marshfield built in 2001 has been completed, but field performance will be monitored over the next one or two winter seasons.
2. Primary cause of distress appears to be lack of freeze/thaw durability of the proprietary mortar mixes. The distress or deterioration of the mortar starts at the joint and works its way out in a series of concentric arcs growing deeper and widening out from the joint as the deterioration advances. Scaling of the mortar surface is also evident in various areas. The surface loss due to scaling is approximately 1/16 in. – 1/8 in. (as of June, 2001).

3. The primary distress (deterioration of the mortar in the dowel bar slots) appears to be causing secondary distress (spalling of the original concrete adjacent to the slots). When the mortar in the slots deteriorates at the joints, the adjacent concrete is left "hanging" and exposed, and when combined with subsequent traffic loadings, appear to be causing spalling of the original concrete.
4. At times on both the I-39 and the STH 13 projects, the mobile mixer was unable to produce a consistent mix as reported in the project engineer's diary.
5. Most states that have tried RDB reported some kind of problem or another. The problems were generally isolated as opposed to large-scale failures. The responses varied as to the best performing mortar mixes, and both material and construction problems were reported. The primary mode of failure was either deterioration or debonding of the mortar material.
6. Air content is not an appropriate parameter for monitoring quality of proprietary patch materials as placed in the field. Freeze/thaw tests are the only direct reliable measure of durability in this case.
7. It appears that the condition of the sealant may be contributing to the distress. In visiting various PCC rehabilitation (partial depth repair) projects around the state, it became clear that projects experiencing the most distress were those with partial sealant systems, i.e. the joint(s) were not *thoroughly* sealed or sections of the sealant came out/deteriorated. The best performing projects were those that had a sound sealant system in place or no sealant system at all. The partially sealed joints seemed to trap water, not allowing it to escape or evaporate and thus perhaps contributed to freeze/thaw distresses.
8. The foam boards are holding water, perhaps accelerating the deterioration of the mortar.
9. It was noticed on the STH 13 project that the caulk used to keep the foam boards in place and prevent mortar from flowing into the joints was a siliconized acrylic sealant (RCS20) made by the General Electric Company. This product is water-soluble and as such, the possibility exists that the water in the mortar mix may have dissolved the caulk and allowed for intrusion of the mortar into the joints. WisDOT specifications call for a silicon sealant to be used (different than a "siliconized", acrylic, water-based sealant).
10. The RDB work on I-39 is providing adequate load transfer.

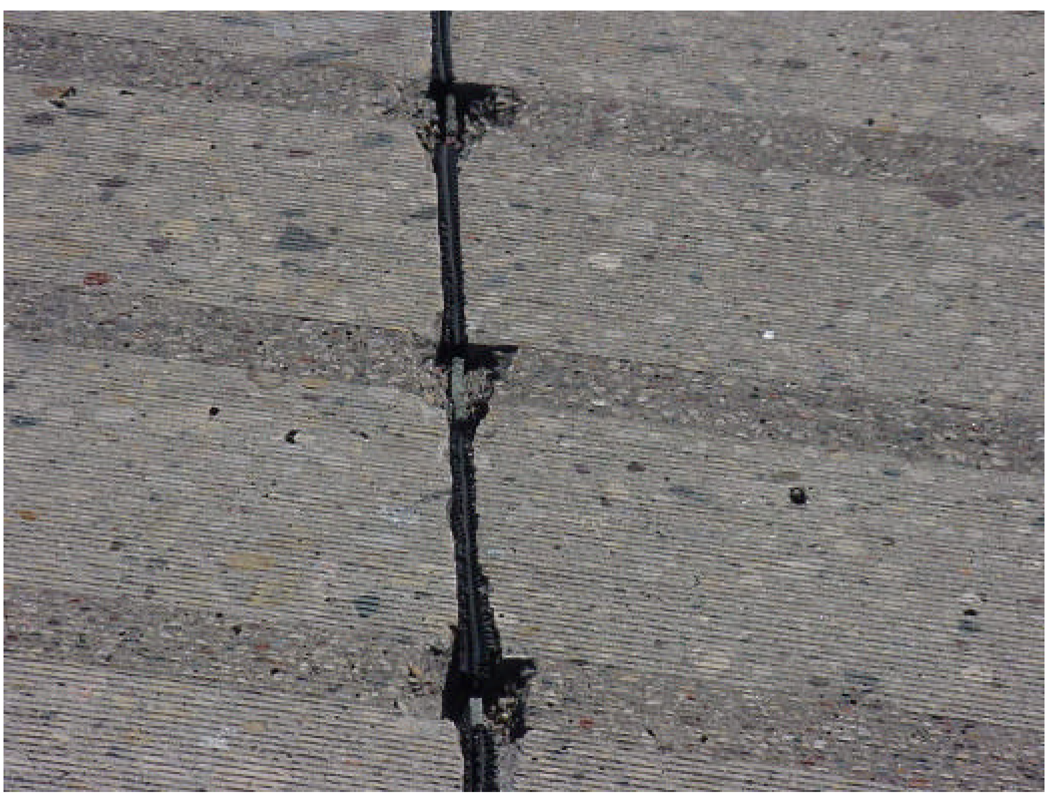
RECOMMENDATIONS

1. Rehabilitate the worst performing sections on I-39 during summer of 2001 with a 3 ½” hot mix asphalt overlay.
2. Perform preventative maintenance by resealing the joints and spraying silane-based sealer on all exposed surfaces of the mortar material to limit future water intrusion into the joint and into the mortar material itself. Slots with deteriorated mortar should be sandblasted to remove the distressed material and refilled with mortar prior to being sealed.
3. Continue the moratorium on RDB work until more knowledge is gained on its long-term viability in Wisconsin.
4. Immediately review alternative rehabilitation techniques for undoweled jointed plain concrete (JPCP) pavements.
5. Continue monitoring the STH 13 RDB project for the next 5 years for performance, along with the physical test results of the cores pulled from the project in 2001.
6. Conduct a Research Advisory Committee (RAC) inquiry with other state DOTs on the best way to rehabilitate distressed RDB work – what has worked the best and what has not, etc.
7. Should the moratorium be lifted in the future, it is recommended to:
    a. require the contractor to demonstrate reproducibility (consistent mortar mix results) with the mobile mixer prior to and during construction or require use of a paddle mixer.
    b. develop a warranty specification for RDB projects.
    c. provide formal direction to contractors on when a particular joint should be addressed with Full Depth Repair vs. RDB due to deteriorated condition of the pavement at the base of the joints.
    d. provide formal direction to contractors on how best to fill voids at the base of the joints (deteriorated concrete at base of joints) as previously discussed.
    e. investigate alternative material and/or method to reestablish the joints; the foam boards currently used hold water which could be contributing to the early deterioration.
    f. more attention should be given to the sawing operation to ensure the saw slots are centered on the joints.
    g. require real silicon caulk to secure and seal the foam boards in place.
8. Use Ground Penetrating Radar (GPR) to estimate extent of joint deterioration and pavement thickness prior to the design process, (i.e. during planning) should RDB work be continued in the future.

APPENDIX A

(Photographs)

Print 1. Close-up of the deterioration of the mortar at the joint. Notice the secondary distress in the form of spalling of the original concrete adjacent to the dowel bar slot.



Print 2. Mortar loss and some slight spalling of the original concrete adjacent to the dowel bar slots.

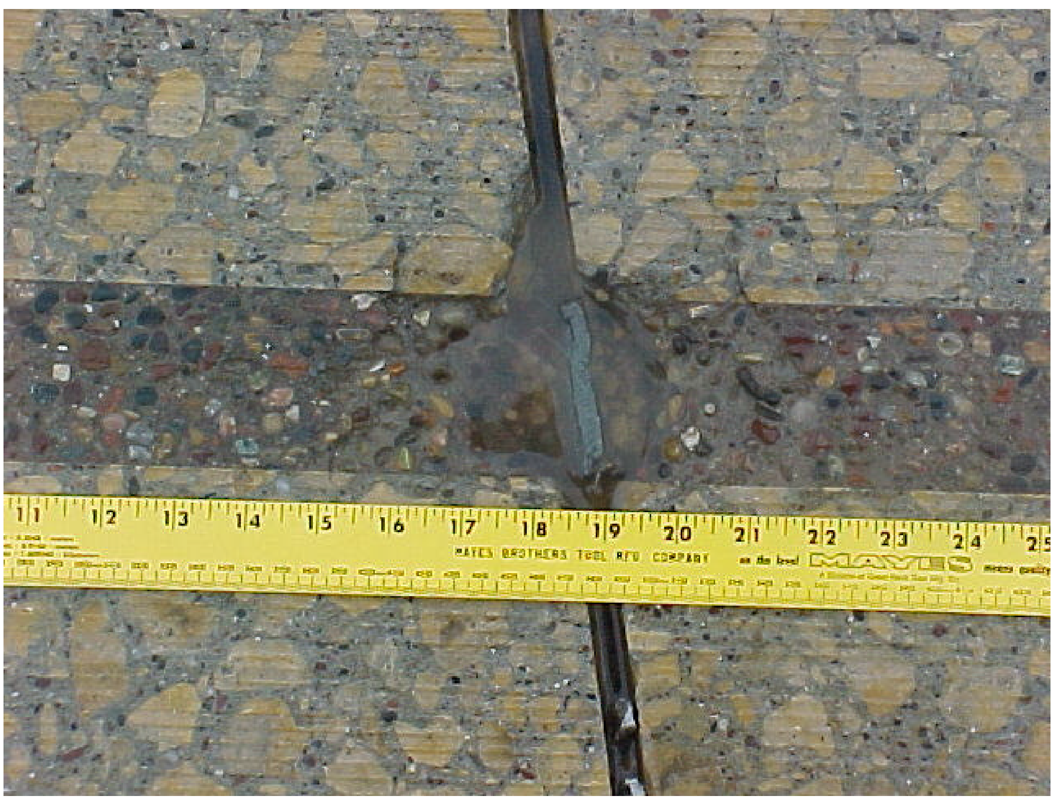
Print 3. An area of severe deterioration of the mortar at the joints on I-39.

Print 4. Mortar deterioration at the joint and secondary spalling distress on I-39.

Print 5. Mortar deterioration and associated spalling on I-39. Photo taken July 9, 2001.

Print 6. Deterioration of the mortar material originating at the joint on US 61.
Notice the stained area near the joint is still holding moisture a couple days after a rain event.

Print 7. Deterioration and slight scaling of the mortar material. Again, notice the stained area near the joint is still holding moisture a couple days after a rain event.



Print 8. View of water ponding in the slot on US 61. Also notice the spalling of the original concrete.

Print 9. Disintegration of the mortar material on US 61.

Print 10. Mortar deterioration and moderate scaling on US 61.

APPENDIX B

Physical Test Results
(Hardened Air Content & Freeze/Thaw Durability)

Table 2 Hardened Air Content & Freeze/Thaw Durability Results

Sample Information (March, 2001)			Air Analysis Data (ASTM C457)				Freeze / Thaw Data (ASTM C666)	
Core Number	Joint Condition	Patch Material	Total Air (%)	Entrained Air (%)	Entrapped Air (%)	Spacing Factor (in.)	Weight Loss (%) 300 Cycles	Weight Loss (%) 600 Cycles
I39-2	No Deterioration	Patch Roc	8.2	6.7	1.5	0.006	12	15
I39-3	Good Condition	Patch Roc	7.7	7.1	0.6	0.008	9	12
I39-5	No Deterioration	Patch Roc	7.1	6.4	0.7	0.007	100	100
I39-6	No Deterioration	Patch Roc	8.1	6.7	1.5	0.006	0	2
I39-7	No Deterioration	Patch Roc	7.6	5.8	1.8	0.010	31	35
I39-8	No Deterioration	Patch Roc	6.6	5.9	0.7	0.006	87	100
I39-9	Light Deterioration	Patch Roc	9.2	6.6	2.5	0.008	12	21
I39-12	Extensive Deterioration	Patch Roc	8.1	6.1	2.0	0.009	100	100
I39-13	Deterioration	Patch Roc	6.1	4.9	1.2	0.006	100	100
I39-14	Heavy Deterioration	Patch Roc	5.1	4.2	0.9	0.006	100	100
I39-17	Heavy Deterioration	Patch Roc	7.3	4.3	2.9	0.013	100	100
18/151-1	No Deterioration	Patch Roc	9.0	7.5	1.4	0.008	9	54
18/151-2	No Deterioration	Patch Roc	8.8	6.4	2.4	0.009	2	83
18/151-3	No Deterioration	Patch Roc	9.4	7.8	1.7	0.006	6	67
18/151-4	No Deterioration	Five Star	5.5	3.8	1.7	0.008	30	100
18/151-5	No Deterioration	Five Star	5.9	4.4	1.4	0.008	2	36
18/151-6	No Deterioration	Five Star	5.9	3.8	2.2	0.013	8	34
18/151-7	No Deterioration	Dayton Superior	6.3	4.3	2.0	0.009	3	62
18/151-8	No Deterioration	Dayton Superior	6.3	4.4	1.9	0.012	0	13
18/151-9	No Deterioration	Dayton Superior	3.5	2.9	0.6	0.007	24	84

Table 3 Freeze/Thaw Durability Test Results

STH 13 in Marshfield

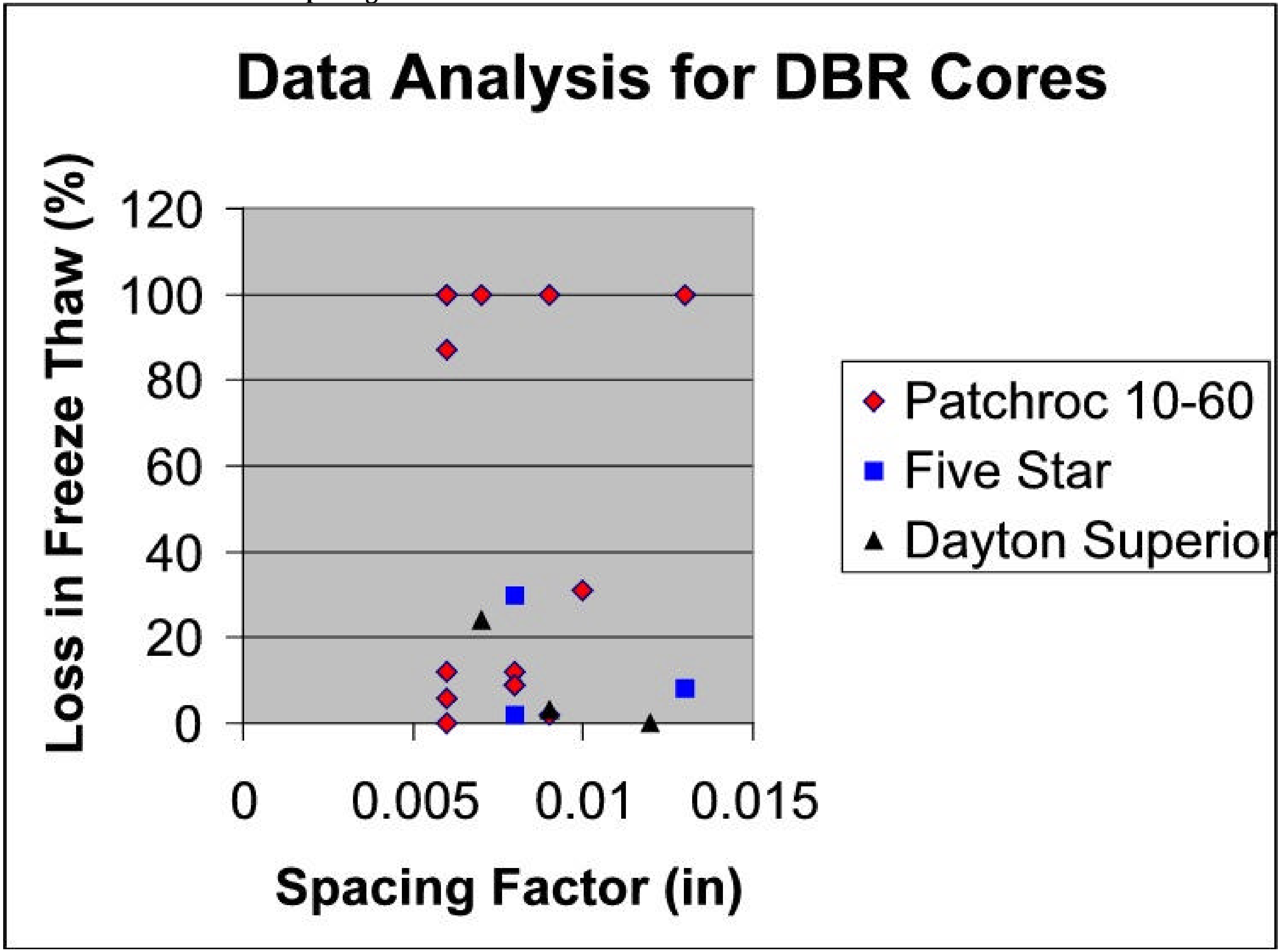
Location	Core #	Patch Material	% Weight Loss (300 cycles)
STH 13	1	American Hwy Technologies	21
STH 13	2	American Hwy Technologies	10
STH 13	3	Tamms Speed Crete 2028	3
STH 13	4	Tamms Speed Crete 2029	0
STH 13	5	American Hwy Technologies	35
STH 13	6	ThoRoc	25
STH 13	7	ThoRoc	11
STH 13	8	MnDOT 3U18 Concrete Mix	-1
STH 13	9	MnDOT 3U18 Concrete Mix	-1
STH 13	10	Tamms Speed Crete 2028	0
STH 13	11	Tamms Speed Crete 2029	0
STH 13	12	MnDOT 3U18 Concrete Mix	0
STH 13	13	MnDOT 3U18 Concrete Mix	0

Note # 1: Negative numbers represent hydration and chloride ion gains.

Note # 2: Shaded areas “passed” freeze/thaw durability testing.

Note # 3: As of December, 2001 all mortar materials used on STH 13 were performing well in the field.

Figure 1 Freeze/Thaw vs. Air Spacing Factor



Graph by James Parry, P.E., WisDOT Materials Lab Supervisor

APPENDIX C

(Falling Weight Deflectometer (FWD) Test Results)

Table 4 Falling Weight Deflectometer (FWD) Test Results

Load Transfer Efficiency (LTE)

Marquette County

Load Transfer 1.00 = 100%

Highway	Direction	Lane	Core Area	Position	Avg Load Transfer
I-39 (3/1/2001)	N	DL	1	REOP	0.88
				RWP	0.82
				CENTER	0.84
I-39 (3/1/2001)	S	PL	11	LEOP	0.93
				LWP	0.88
				CENTER	0.89
I-39 (3/1/2001)	S	DL	13	REOP	0.79
				RWP	0.81
				CENTER	0.76
I-39 (3/1/2001)	S	DL	14	REOP	0.89
				RWP	0.87
				CENTER	0.79
I-39 (3/1/2001)	S	DL	18	REOP	0.90
				RWP	0.88
				CENTER	0.86
US 18/151 (3/8/2001)	W	DL	1	REOP	0.61
				RWP	0.76
				CENTER	0.44
US 18/151 (3/8/2001)	W	PL		LEOP	N/A
				LWP	0.63
				CENTER	0.58
US 18/151 (3/8/2001)	W	PL		LEOP	0.60
				LWP	0.72
				CENTER	0.54

REOP = Right Edge of Pavement
LEOP = Left Edge of Pavement
RWP = Right Wheelpath
LWP = Left Wheelpath
Center = Between Left and Right Wheelpaths
N/A = No measurements taken in this location.

Table 5 Follow-up FWD Test Results on I-39 (Percent Load Transfer)

Measurement Dates: **7/24/01 - 7/25/01**

Ambient Air Temp. = 80-90°F
24th - Sunny Sites 1 thru 4, 25th – Cldy to Mostly Cldy Sites 5 thru 8

85-115°
Pavement Temp. = F

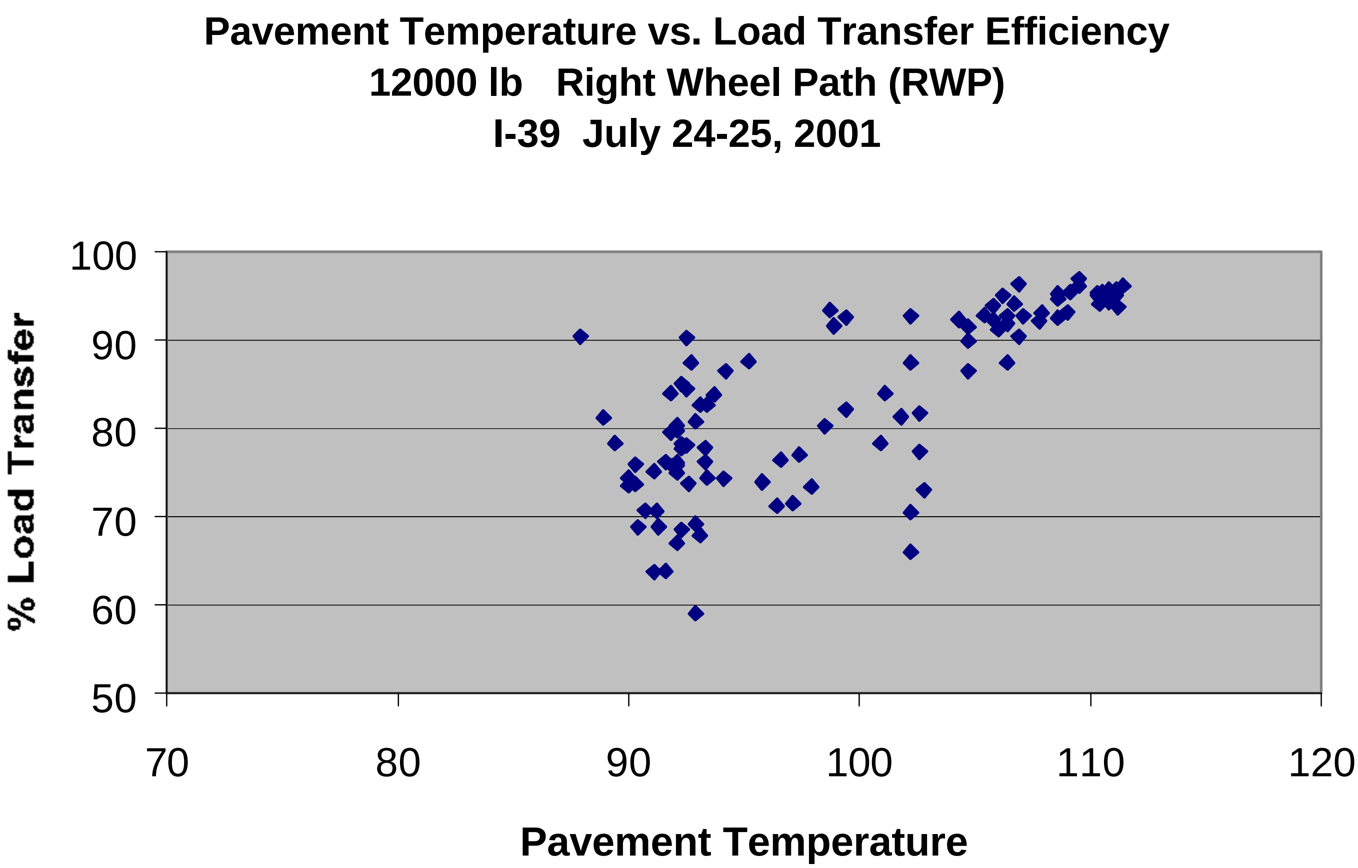
Transverse Position: Right Wheelpath

Percent Load Transfer

Transverse Joint Position	Load		Site 1	2	3	4	5	6	7	8
Right Wheelpath	**4700 lb**	**Min**	69	69	89	82	59	55	68	47
		Max	95	96	96	97	85	80	92	87
		Avg	80	82	93	91	74	71	82	65
	9000 lb	**Min**	73	67	93	88	63	57	76	43
		Max	95	93	98	96	88	80	88	83
		Avg	82	82	95	93	73	73	82	59
	11500 lb	**Min**	71	66	93	87	64	59	74	44
		Max	93	93	97	96	90	79	90	82
		Avg	81	82	95	93	74	73	82	59
	21000 lb	**Min**	68	65	92	86	63	59	74	40
		Max	91	89	96	94	88	79	88	79
		Avg	79	79	94	91	73	72	80	54
Center	**4700 lb**	**Min**	60	48	92	91		50	54	34
		Max	94	96	10	97		63	68	67
		Avg	76	67	96	94		57	62	47
	9000 lb	**Min**	60	53	95	90		53	61	33
		Max	94	95	101	97		67	67	67
		Avg	78	67	98	94		57	64	43
	11500 lb	**Min**	61	53	95	88		51	62	32
		Max	96	96	98	95		67	67	70
		Avg	78	69	97	93		57	64	44
	21000 lb	**Min**	58	54	94	85		53	59	32
		Max	93	91	97	94		67	66	66
		Avg	74	66	95	90		58	62	42

Site No.	Dowelled	DIR	Lane	Location	Jt. Spalling
1	Yes	N	DL	Aprx MP 102.3	LT 1/4” Long. – No Depth
2	Yes	N	DL	Aprx MP 105	LT 1/4” Long. – 1/4” to 1/2” Depth
3	Yes	N	DL	Aprx MP 123	1/2” to 3/4” Long. – 1/4+ Depth
4	Yes	N	DL	Aprx MP 126.5	3/4”+ Long. – 1/2” to 3/4” Depth
5	Yes	S	DL	Aprx MP 112	1 1/2” to 2 1/2” Long. – 1/4” to 1/2” Depth
6	Yes	S	DL	Aprx MP 102.3	4”+ Long. – 3/4”+ Depth – Additional spalling outside mortar area 3/4” each side
7	Yes	S	DL	Aprx MP 100.5	3”+ Long. – 1/2” to 3/4” Depth – Additional spalling outside mortar area 1/2”+ each side
8	**No**	N	DL	Aprx MP 133.4	No discernable spalling

Figure 2   Pavement Temperature vs. Load Transfer Efficiency on I-39 (Follow-up FWD Tests)



Note, the graph above does *not* include the undoweled section that was tested (Site 8).

APPENDIX D

(Implementation Plan)

Research Study Recommendation and Implementation Plan

Highway Research Study ID: RED-01-02
WisDOT Report #: RED-05-01
Title: "Report on Early Distress (RED), Retrofit Dowel Bars on I-39"

Background Problem Statement: This report presents findings of an investigation into a Retrofit Dowel Bar (RDB) project that was experiencing early distress in the form of deterioration of the mortar in the dowel bar slots. RDB is a concrete pavement rehabilitation technique where, in this case, three slots are cut into the pavement in each wheel path, dowel bars are inserted into the slots and backfilled with a proprietary mortar mix to tie the adjacent concrete slabs together. The pavement is then diamond ground after the work is completed to restore a smooth ride to the original pavement. The reasons why this technique was chosen include the following: 1.) it improves load transfer between adjacent concrete slabs, 2.) it extends the pavement's service life, and 3.) it restores a smooth ride to the traveling public. In addition, this technique addresses the root of the problem (faulted joints due to a lack of a load transfer system) and not just the symptoms (poor ride). As a result of the problems that have arisen with this technique, WisDOT issued a statewide moratorium for all RDB work until more knowledge is gained on its long-term viability in Wisconsin.

WisDOT Study Manager: Joe Wilson

Study Conclusions:

1. At the current time there is insufficient data to make a decision to resume letting RDB contracts. Laboratory analysis of the cores from the RDB research project on STH 13 in Marshfield built in 2001 has been completed, but field performance will be monitored over the next 1-2 winter seasons.
2. Primary cause of distress appears to be lack of freeze/thaw durability of the proprietary mortar mixes. The distress or deterioration of the mortar starts at the joint and work its way out in a series of concentric arcs growing deeper and widening out from the joint as the deterioration advances. Scaling of the mortar surface is also evident in various areas. The surface loss due to scaling is approximately 1/16 in. – 1/8 in. (as of June, 2001).
3. The primary distress (deterioration of the mortar in the dowel bar slots) appears to be causing secondary distress (spalling of the original concrete adjacent to the slots). When the mortar in the slots deteriorates at the joints, the adjacent concrete is left "hanging" and exposed, and when combined with subsequent traffic loadings, appears to be causing spalling of the original concrete.
4. At times on both the I-39 and the STH 13 projects, the mobile mixer was unable to produce a consistent mix.
5. Most states that have tried RDB reported some kind of problem or another. The problems were generally isolated as opposed to large-scale failures. The responses varied as to the best performing mortar mixes, and both material and construction problems were reported. The primary mode of failure was either deterioration or debonding of the mortar material.
6. Air content is not an appropriate parameter for monitoring quality of proprietary patch materials as placed in the field. Freeze/thaw tests are the only direct reliable measure of durability that we have in this case.
7. It appears that the condition of the sealant may be contributing to the distress. In visiting various PCC rehabilitation (partial depth repair) projects around the state, it became clear that projects experiencing the most distress were those with partial sealant systems, i.e. the joint(s) were not *thoroughly* sealed or sections of the sealant came out/deteriorated. The best performing projects were those that had a sound sealant system in place or no sealant system at all. The partially sealed joints seemed to trap water, not allowing it to escape or evaporate and thus perhaps contributed to freeze/thaw distresses.
8. The foam boards are holding water, perhaps accelerating the deterioration of the mortar.
9. It was noticed on the STH 13 project that the caulk used to keep the foam boards in place and prevent mortar from flowing into the joints was a siliconized, acrylic, water-based sealant (RCS20) made by the General Electric Company. This product is water soluble and as such, the possibility exists that the water in the mortar mix may have dissolved the caulking and allowed for intrusion of the mortar into the joints. A check of WisDOT specifications found that a silicon sealant is called for (different than a "siliconized", acrylic, water-based sealant).
10. The RDB work on I-39 is providing adequate load transfer.

Study Recommendations

1. Rehabilitate the worst performing sections on I-39 during summer of 2001 with a 3 ½” hot mix asphalt overlay.
2. Perform preventative maintenance by resealing the joints and spraying a silane-based sealer on all exposed surfaces of the mortar material to limit future water intrusion into the joint and into the mortar material itself. Slots with deteriorated mortar should be sandblasted to remove the distressed material and refilled with mortar prior to being sealed.
3. Continue the moratorium on RDB work until more knowledge is gained on its long-term viability in Wisconsin.
4. Immediately review alternative rehabilitation techniques for undoweled jointed plain concrete (JPCP) pavements.
5. Continue monitoring the STH 13 RDB project for the next 5 years for performance, along with the physical test results of the cores pulled from the project in 2001.
6. Conduct a Research Advisory Committee (RAC) inquiry with other state DOTs on the best way to rehabilitate distressed RDB work – what has worked the best and what has not, etc.
7. Should the moratorium be lifted in the future, it is recommended to:
    a. require the contractor to demonstrate reproducibility (consistent mortar mix results) with the mobile mixer prior to and during construction or require use of a paddle mixer.
    b. develop a warranty specification for RDB projects.
    c. provide formal direction to contractors on when a particular joint should be addressed with Full Depth Repair vs. RDB due to deteriorated condition of the pavement at the base of the joints.
    d. provide formal direction to contractors on how best to fill voids at the base of the joints (deteriorated concrete at base of joints) as previously discussed.
    e. investigate alternative material and/or method to reestablish the joints; the foam boards currently used hold water which could be contributing to the early deterioration.
    f. more attention should be given to the sawing operation to ensure the saw slots are centered on the joints.
    g. require real silicon caulk to secure and seal the foam boards in place.
8. Use Ground Penetrating Radar (GPR) to estimate extent of joint deterioration and pavement thickness prior to the design process, (i.e. during planning) should RDB work be continued in the future.

Implementation Plans:

1. Present the findings and recommendations of this report to the Concrete Pavement Structural Design User Group for discussion, input & approval (this has already been done).
2. Continue the moratorium on RDB work until more knowledge is gained on long-term performance.
3. Immediately review alternative rehabilitation techniques for undoweled jointed plain concrete pavements.
4. Conduct a Research Advisory Committee (RAC) inquiry with other state DOTs on the best way to rehabilitate distressed RDB work – what has worked the best and what has not etc. Included in this plan is to gather suggestions and input from WisDOT District Pavement Engineers.
5. Begin immediate rehabilitation work on the sections experiencing the most distress.

Report Distribution: Internal and External

Administrative Comment:

Please Return to Study Manager: **Joe Wilson,** **DTID/BHC/TAU – Truax Center**